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Dating bog bodies by means of ^{14}C -AMS

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Abstract

We have made efforts to date a substantial number of bodies from northwest European peat bogs by means of ^{14}C . In our research, we compared materials such as skin, hair, bone, textile, leather and wood where available. Most of the bodies we investigated were found to date from the Late Iron Age/Roman period (c. 2nd century BC–4th century AD). Our data set shows that bog bodies in general can indeed be successfully dated by means of ^{14}C analysis. Our results contradict comments in the literature (e.g. C.S. Briggs, Did they fall or were they pushed? Some unresolved questions about bog bodies, in: R.C. Turner, R.G. Scaife (Eds.), *Bog Bodies—New Discoveries and New Perspectives*, British Museum Press, London, 1995, pp. 168–182) to the effect that ‘peat bogs can age corpses so as to distort completely the usefulness of Radiocarbon’.

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Keywords: Bog bodies; Radiocarbon; Peat bogs; Isotopes; Dating

1. Introduction

Many human bodies have been found in the peatlands of north and northwest Europe. Most of the bodies came to light in the 18th, 19th and early 20th centuries. On more than one occasion those early finds frightened the peat cutters who chanced upon them to death. In those days, peat was a major source of energy in northwest Europe. Many bog bodies did not survive their discovery for very long. Quite a few were reburied in local churchyards; others were thrown back into the bog or cut into pieces which were taken to different institutions. Fortunately several bodies found their way into museums in the Netherlands, Germany, Denmark, Ireland and England. Among the most famous bodies are Tollund Man, Grauballe Man, Lindow Man, Windeby Girl and Yde Girl [40].

The best preserved human remains come from raised bogs. A crucial factor in their preservation is the presence of a polysaccharide (Sphagnum) in the Sphagnum moss found in such bogs (for details see [40], 18). In

raised bogs, soft tissues, nails, hair, intestines and organs like kidneys and the liver may survive, as well as any clothing made of leather or wool (garments made of plant materials dissolve).

Bones decalcify in raised bogs. They deform and may ultimately dissolve completely. Fig. 1 shows an example of bodies preserved in a raised bog. These bodies, of two males, were found in Bourtanger Moor near Emmen, the Netherlands, in 1904. The flat remains consist mainly of skin and hair; the few bones that have survived are deformed. The age of this find, which is known as the ‘Weerdinge couple’, is 2000 years.

Establishing the age of bog bodies was for a long time a major problem as most of the bodies came to light unaccompanied by objects that could be dated on the basis of typological evidence. In the past, this led to interesting speculations, as in the case of for example Haraldskaer Woman, who was in 1835 identified as Queen Gunhild of the Viking Age (we now know that the body actually predates this queen’s reign by 1500 years). Later, attempts were made to date bog bodies indirectly by means of palynological research. In the 1950s the first efforts were made to obtain radiocarbon dates of bog bodies. The first body to be dated in this way was that of Grauballe Man, which was discovered

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Fig. 1. The “Weerdinge Couple”—two men whose bodies were found in Bourtanger Moor near Weerdinge, the Netherlands, in 1904. The men died approximately 2000 years ago. Drents Museum, Assen.

in 1952 [33]. It was another 20 years before the next two bodies, of Tollund Man and Elling Woman, were to be radiocarbon dated [34]. Until the discovery of Lindow Man, in 1984, radiocarbon analysis was not considered an ideal means for dating bog bodies. This is understandable, because a substantial amount of bone or skin was needed for conventional radiocarbon dating, and museum curators were of course reluctant to sacrifice the necessary samples. Moreover, bog bodies were not a ‘hot issue’ in those days.

With the discovery of Lindow Man in the 1980s and the development of AMS dating, which requires samples of only 1 mg, things started to change. The published dates of Lindow Man however initiated an intense debate. The peat surrounding the body yielded ^{14}C dates of 750–200 BC, whereas samples of the body itself were in Oxford found to date from the 1st century AD and in Harwell from the 5th–first half of the 6th century AD

[10,11,27,31]. There is still no satisfying explanation for the difference in the dates obtained by the two laboratories [20]. The Oxford dates seem to be the more likely of the two. This controversy led some archaeologists to question the reliability of radiocarbon dates obtained for bog bodies [4]. It is true that bog bodies are not the most ideal subjects for ^{14}C dating, as will be discussed below. The results of our research nevertheless show that reliable ^{14}C dates can indeed be obtained for bog bodies.

Radiocarbon dating of bog bodies cannot be considered a straightforward, standard procedure because of the nature of the material involved. The highly humified water of the peat bog which preserved the tissue also subjected the biological remains to a tanning process. A complicating factor is that carbon atoms from the water can cause contamination that will interfere with the determination and will usually result in an age that is too

old. The peat context in which a body is found may moreover be several centuries older than the body itself, as was demonstrated in the case of Lindow Man.

Any sample subjected to ^{14}C dating must be pretreated prior to the determination to remove such carbon-containing components relating to different periods (i.e. contamination with allochthonous carbon). The required pretreatment procedure has been summarised by [23]. It usually comprises a physical pretreatment step designed to remove contaminants (substances not of interest in the subsequent analysis, such as rootlets, which are removed e.g. by sieving) and chemical pretreatment steps, the most common of which is AAA (Acid–Alkali–Acid), in which the datable fraction of the sample is extracted. A sample's ' ^{14}C -quality' can be inferred from the $\delta^{13}\text{C}$ value obtained and the measured carbon content [24].

As already mentioned above, the introduction of AMS, involving samples of only a few milligrams, made it feasible to date bog bodies by means of ^{14}C (see e.g. [18,22]). In this report we present AMS ^{14}C dates obtained for a substantial group of northwest European bog bodies. Most of these bog bodies have now been dated for the first time. We also redated some bodies that had previously been dated by other laboratories, first by conventional means and more recently by means of AMS, such as the famous bodies of Tollund Man and Elling Woman (see [19] for AMS dates). In our research we also compared different materials (bone, hair, skin, clothing), and studied the effects of chemical pretreatment. We show that by careful sampling and pretreatment, bog bodies can indeed yield reliable ^{14}C dates.

2. Methods

All the analyses whose results are presented here were performed by the AMS facility of the University of Groningen [36]. After pretreatment, the samples were combusted by an automated Elemental Analyser/Mass Spectrometer (EA/MS) combination [1]. The EA combusts samples to CO_2 , which is subsequently purified. The MS yields a $\delta^{13}\text{C}$ value for the sample. The combusted CO_2 is cryogenically trapped and reduced to graphite, which is compressed into a target for the ion source of the AMS. The AMS also yields a $\delta^{13}\text{C}$ value, though this value is less precise than that obtained with the MS. The AMS value is used for correction in isotopic fractionation and serves as a diagnostic tool in AMS measurement procedures.

Samples must usually be submitted to chemical pretreatment to obtain the required datable fraction, i.e. material (in terms of carbon atoms) representing the proper age of the find—in our case a bog body. Bog bodies were buried in peat for a long period of time prior

to their discovery. The main contaminants in the case of samples of bog bodies are humic and fulvic acid from the peat.

We employed the 'standard' AAA pretreatment procedure described by [23] for the bog bodies. In the first acid step of this procedure, carbonates, resins and fulvic acids are removed. Tannic acids and lignin are removed in the subsequent alkali step. The aim of the final acid step is to remove any CO_2 adsorbed during the alkali treatment. The extracts are separated from the residue.

In some cases it may be useful to determine the age of the compound removed by means of extraction. This information may indicate whether the original sample contained foreign material of a different age. If so, it is to be hoped that the contaminant has been removed completely. If, on the other hand, the extracted fraction containing any contaminant is found to be of the same age as the residue, the date obtained may be considered to be reliable.

From medieval shoes made of leather recovered from humic soils it is known that any contaminants present will usually be humic and fulvic acid from the soil. In such cases, an extract obtained in alkali treatment will contain no residue [25]. Hot water treatment appears to suffice to extract such soil components.

Peat has a low pH, so the bog bodies may be considered to have already undergone an acid treatment. Some of the samples were therefore not subjected to pretreatment, but were combusted directly by the EA/MS.

3. Results: catalogue of dated bog bodies

We ^{14}C -analysed skin, hair and bone samples of bog bodies where available; in addition, we also analysed any associated wood and fur/leather and wool from clothing. The data presented below comprise the name/sex of the bog body, the findspot, repository, associated finds, ^{14}C dates (in years BP and calibrated dates) and other relevant results of isotopic analysis such as $\delta^{13}\text{C}$ values. The survey includes a grand total of 40 bog bodies from 35 findspots (some finds consist of several bodies).

The ^{14}C dates are reported in years BP, with correction for isotopic fractionation using the stable isotope ratio $\delta^{13}\text{C}$. Note that the analyses yielded two different $\delta^{13}\text{C}$ values—one obtained with the aid of the AMS and one with the aid of an IRMS (Mass Spectrometer for stable isotopes). The first values were used only for fractionation correction; they are not quoted below as they are not very accurate. The second values were obtained in the actual combustion of the samples. Those values are considered to be reliable $\delta^{13}\text{C}$ values; they are quoted in the tables below.

The ^{14}C dates obtained had to be calibrated to obtain calendar dates. This was done using the Groningen

Radiocarbon Calibration Program [35], updated with the latest recommended calibration curve Intcal98 [32]. The calibrated results are given as 1σ probability ranges [5,35], rounded off to the nearest 5.

In the following catalogue the bodies have been grouped per country, in the order of the year of their discovery (indicated between brackets). The information provided under ‘literature’ comprises the body’s number in Alfred Dieck’s catalogue [6] and some of the most recent publications (in which all the older sources can be found).

Denmark

1: Elling Woman (1938)

Findspot: Bjaeldskovdal, Viborg *Amt*

Associated objects: two fur capes, a woollen belt and a leather halter

Repository: Silkeborg Museum, Silkeborg (inv. No. Nat. Mus. Copenhagen: 508–1938)

Literature: [6], No. 506; [7]; [40], 34–35, 76–77, 84, 103, 141, 145–147, 155, 194; [19], 287

Expected date: previous K and AAR ^{14}C measurements

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
K-2876	soft tissue		2170	55			
K-2877	fur cape		2120	55			
AAR-3415	cape hairs		2195	40	–23.80		
GrA-8012	fur cape	AAA	3390	70	–24.60	n/a	1770–1605, 1560–1530 BC
GrA-10154	fur cape	none	940	40	–22.26	45.2	AD 1030–1155
GrA-13434	fur cape	none	1750	40	–24.56	48.5	AD 240–375
GrA-14315	fur cape	AAA	2210	30	–24.19	43.0	355–205 BC
GrA-14321	fur cape	AAA	1900	30	n/a	n/a	AD 75–130
GrA-15637	fur cape	AAA	2350	50	–24.37	48.4	515–365 BC

2: Tollund Man (1950)

Findspot: Bjaeldskovdal, Viborg *Amt*

Associated objects: a fur cap, a leather belt and rope

Repository: Silkeborg Museum, Silkeborg (inv. No. 201–1950)

Literature: [6], No. 646; [7]; [40], 16–18, 34, 61, 76–77, 84, 97, 103, 108–111, 118, 124, 133, 135–136, 141, 144–147, 155, 195; [19], 287

Expected date: previous K and AAR ^{14}C measurements

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
K-2814A	soft tissue		2150	75			
K-2814A	soft tissue		2260	75			
K-2814B	soft tissue		2110	75			
K-2814B	soft tissue		2140	55			
AAR-3328	bone		2345	40	–21.10		
GrA-8028	skin	AAA	1950	80	–21.09	50.3	AD 45–205
GrA-10188	skin	none	2450	50	–23.88	52.9	760–410 BC
GrA-14179	skin	AAA	2290	30	–23.56	49.0	395–360, 270–265 BC

Germany, Lower Saxony

3: Bareler Moor Girl (1784)

Findspot: Bareler Moor, *Landkreis* Oldenburg

Associated objects: none

Repository: Staatliches Museum für Natur und Mensch, Oldenburg (inv. No. 1687)

Literature: [14]; [40], 39–40, 192

Expected date:

Radiocarbon result:

The bog body ^{14}C dates obtained by the two Groningen laboratories are identified by the laboratory codes GrA—Groningen (AMS) and GrN—Groningen (conventional method). Some bog bodies dated by other ^{14}C laboratories have been included for the sake of completeness. The laboratories concerned are identified by their own laboratory codes: OxA—Oxford (AMS), AAR—Aarhus (AMS), K—Copenhagen (conventional method), KI—Kiel (conventional method) and KIA—Kiel (AMS).

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-9153	skin	AAA	1710	50	−21.82	49.1	AD 260–395

4: Marx-Etzel (1817)

Findspot: Hilgenmoor, *Landkreis* Wittmund

Associated objects: posts, a sleeveless woollen tunic, a pair of woollen knee-length breeches, remains of a third woollen garment and a leather shoe

Repository: *Niedersächsisches Landesmuseum*, Hanover (without inv. No.)

Literature: [6], No. 24; [30], 19; [40], 49, 127, 147, 166, 192

Expected date: Iron Age (based on textile typology)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-8024	wool	alkaline	1750	80	−24.50	46.2	AD 140–395
GrA-12418	wool	AAA	1970	70	−23.58	51.9	AD 45–125

5: Marx-Stapelstein (1861)

Findspot: Hilgenmoor, *Landkreis* Wittmund

Associated objects: remains of several woollen garments

Repository: *Niedersächsisches Landesmuseum*, Hanover (without inv. No.)

Literature: [6], No. 140; [13], 112; [30], 19–20

Expected date: Iron Age (based on textile typology); mid 7th –1st cent. BC (based on palynological evidence)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-9155	wool-1	AAA	170	40	−24.20	43.0	AD 1665–1810, 1920–1950
GrA-10289	wool-1	none	280	40	−24.29	44.4	AD 1520–1580, 1625–1660
GrA-12425	wool-2	AAA	1780	50	−23.85	58.6	AD 135–385
GrA-14782	wool-2	none	1840	50	−24.21	47.3	AD 125–240
GrA-14783	wool-3	none	1910	50	−25.65	44.3	AD 5–205

6: Oberaltendorf Man (1895)

Findspot: Kehdinger Moor, *Landkreis* Cuxhaven

Associated objects: a woollen cloak, a tunic, a pair of breeches, leg wrappings, shoes and two silver *Kapselberlocks*

Repository: *Schwedenspeicher-Museum*, Stade (inv. No. 930)

Literature: [6], No. 297; [39], 139–141; [40], 43, 76–77, 79, 93–94, 127, 146–147

Expected date: 1st–4th cent. AD (based on silver ornaments)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-1351	textile	A	1690	50	−23.89	44.4	AD 260–415
GrA-1352	hair	A	1750	50	−21.12	39.8	AD 235–380

7: Neu-Versen Man/Roter Franz (1900)

Findspot: Bourtangier Moor, *Landkreis* Emsland

Associated object(s): woollen thread (and woollen cloak?)

Repository: *Niedersächsisches Landesmuseum*, Hanover (inv. No. 17351)

Literature: [6], No. 310; [39], 141; [28]; [40], 76–77, 79, 97, 141

Expected date: 1st–2nd cent. AD (based on palynological evidence)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-1532	hair	none	1730	50	−20.00	42.6	AD 245–385
GrA-16196	hair	AAA	1760	70	−22.43	45.0	AD 135–385

8: Brammer Man (1903)

Findspot: Kreepen, *Landkreis* Verden

Associated objects: branches, twigs and stones

Repository: body kept in *Museum für Vor- und Frühgeschichte* in Berlin until 1945; tuft of hair in *Moor- und Fehnmuseum*, Elisabethfehn

Literature: [6], No. 331; [40], 89; [41]

Expected date:

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1 σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1 σ)
GrA-8014	hair	AAA	390	60	−19.85	41.4	AD 1440–1520, 1585–1625
GrA-12208	hair	none	540	50	−20.59	52.8	AD 1325–1345, 1395–1435

9: Bernuthsfeld Man (1907)

Findspot: Hogehehn Moor, *Landkreis* Aurich

Associated object(s): a stick, two woollen cloaks, leg wrappings, a sleeved tunic, two leather belts and a leather knife sheath

Repository: *Ostfriesisches Landesmuseum*, Emden (inv. No. 0952 097 072)

Literature: [6], No. 354; [39], 141–142; [40], 76–77, 79, 93, 95, 100, 127–128, 147, 176, 192

Expected date: Middle Ages (based on textile typology)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1 σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1 σ)
GrA-782	hair	none	1290	45	−20.35	n/a	AD 680–775

10: Kayhausen Boy (1922)

Findspot: Kayhausermoor, *Landkreis* Ammerland

Associated objects: fur cape, textile

Repository: *Landesmuseum für Natur und Mensch*, Oldenburg (inv. No. 5935)

Literature: [6], No. 433; [29], 65–79; [39], 142; [40], 76–77, 81–82, 93, 97, 113, 135, 141, 161, 166–167, 192.

Expected date: 1st–2nd cent. AD (based on palynological evidence)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1 σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1 σ)
GrA-1393	hair	A	2160	50	−21.17	40.9	355–295, 255–115 BC
GrA-9150	bone	collagen	2920	50	−23.54	19.4	1250–1020 BC
GrA-14314	wool	AAA	2240	30	−25.37	42.8	380–355, 295–210 BC
GrA-14404	bone	collagen	2360	40	−21.79	40.0	515–385 BC
GrA-14780	wool	none	45	45	−27.60	44.2	

11: Jühdenerfeld Man (1934)

Findspot: Jühdenerfeld (also known as Bockhornerfeld), *Landkreis* Friesland

Associated objects: posts, woollen cloak, fur cape

Repository: *Landesmuseum für Natur und Mensch*, Oldenburg (inv. No. 5936)

Literature: [6], No. 471; [39], 142; [40], 76–77, 79, 97, 99, 192

Expected date: 4th–1st cent. BC (based on palynological evidence)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1 σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1 σ)
GrA-1325	hair	A	1975	50	−20.91	39.5	40 BC–AD 75
GrA-9149	skin	AAA	2090	50	−23.66	49.7	170–45 BC

12: Husbäke Man (1936)

Findspot: Vehnemoor, *Landkreis* Oldenburg

Associated objects: none

Repository: *Landesmuseum für Natur und Mensch*, Oldenburg (inv. No. 5933)

Literature: [6], No. 480; [29], 70; [39]; [40], 76–77, 79, 97, 113, 192

Expected date: 6th–3rd cent. BC (based on palynological evidence)

Radiocarbon results:

Lab. no.	Sample	Pre-treatment	^{14}C (BP)	Error (1 σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1 σ)
GrA-1350	hair	A	1880	50	n/a	37.7	AD 75–215
GrA-9148	skin	AAA	2480	50	−23.55	47.5	765–520 BC
GrA-10153	skin	none	2370	50	−25.08	55.4	520–385 BC
GrA-15631	hair	AAA	1690	60	−22.80	44.3	AD 260–420

13: Hunteburg Foot (1938)Findspot: Grossen Moor, *Landkreis* Diepholz

Associated object(s): (left) shoe, leather, post

Repository: *Niedersächsisches Landesmuseum*, Hanover (inv. No. 1940:38)

Literature: [6], No. 505; [12], 116–119; [39], 143; [40], 76–77, 79, 192

Expected date: 13th–mid-14th cent. AD (based on shoe typology)

Radiocarbon result:

Lab. no.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
GrA-914	skin	water	750	70	−20.58	45.3	AD 1215–1300

14: Sedelsberger Dose Man (1939)Findspot: Sedelsberger Dose, *Landkreis* Cloppenburg

Associated objects: none

Repository: *Landesmuseum für Natur und Mensch*, Oldenburg (inv. No. 5775)

Expected date: 11th–12th cent. AD (based on palynological evidence)

Literature: [6], No. 510; [16], 59–63; [29], 65

Radiocarbon result:

Lab. no.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
GrA-9151	bone	collagen	900	45	−20.34	42.3	AD 1040–1210

15: Neu-England Man (1941)Findspot: Lengener Moor, *Landkreis* Oldenburg

Associated objects: none

Repository: *Landesmuseum für Natur und Mensch*, Oldenburg (inv. No. 5810)

Literature: [6], No. 523; [39], 143–144; [40], 76–77, 79–80, 192

Expected date: 2nd–4th cent. AD (based on palynological evidence)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
GrA-1349	hair	A	1775	50	n/a	39.0	AD 135–340
GrA-9196	skin	AAA	1800	50	−23.09	39.9	AD 135–255, 300–320

16: Hunteburg Men (I and II) (1949)Findspot: Grossen Moor, *Landkreis* Diepholz

Associated objects: two woollen cloaks, small bunch of flowering heather

Repository: *Niedersächsisches Landesmuseum*, Hanover (inv. No. 185:50)

Literature: [6], Nos. 633 and 634; [39]; [40]

Expected date: Iron Age (based on textile typology); 5th–1st cent. BC (based on palynological evidence)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
GrA-1535	hair	none	1680	50	−19.91	44.9	AD 260–275, 325–420
GrA-16197	hair	AAA	1710	70	n/a	43.2	AD 245–415

17: Hunteburg III (1949)Findspot: Grossen Moor, *Landkreis* Diepholz

Associated objects: piece of animal skin (deer?)

Repository: *Niedersächsisches Landesmuseum*, Hanover (inv. No. 185:50)

Literature: [39], 145; [40], 76–77, 180

Expected date:

Radiocarbon result(s):

Lab. No.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
GrA-508	bone	collagen	1975	45	−20.56	n/a	40 BC–AD 75
GrA-509	bone	residue	1970	40	−23.75	n/a	35 BC–AD 75

18: Bentstreek Foot (1955)Findspot: Lengener Moor, *Landkreis* Wittmund

Associated objects: leather shoe, textile

Repository: *Niedersächsisches Landesmuseum*, Hanover (inv. No. 142:55)

Literature: [6], No. 668; [12], 114; [13]; [40], 91

Expected date: 10th–9th cent. BC (based on palynological evidence)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-9156	leather	AAA	1830	50	–23.67	48.7	AD 125–240
GrA-10288	leather	none	1440	40	–25.48	54.4	AD 600–655
GrA-12416	leather	AAA	1960	60	–21.18	48.4	40 BC–AD 125
GrA-14311	leather	AAA	1870	30	–24.41	44.5	AD 85–215
GrA-14681	leather	none	1580	50	–26.02	59.8	AD 430–535

19: Johann Spieker (1978)

Findspot: Goldenstedter Moor, *Landkreis* Vechta

Associated objects: coins, remains of prayer book, buttons, woollen jacket

Repository: *Landesmuseum für Natur und Mensch*, Oldenburg (inv. No. C 863)

Literature: [15], 14–16; [17]

Expected date: 1828 AD (based on historical information)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-19543	wood	AAA	155	40	–25.69	44.1	AD 1670–1875, 1915–1950
GrA-19544	hair	AAA	175	40	–20.53	44.6	AD 1665–1810, 1925–1950
GrA-19547	textile	AAA	225	40	–24.64	42.7	AD 1640–1675, 1760–1805, 1935–1945

Germany, Schleswig-Holstein

20: Rendswühren Man (1871)

Findspot: Grossen Moor, *Landkreis* Plön

Associated objects: fur cape and woollen cloak

Repository: *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (KS, without inv. No.; textile: KS 3352)

Literature: [6], No. 170; [8], 20–23; [30], 22; [39], 145; [40], 49–50, 76–77, 81, 121, 193

Expected date: Iron Age (based on textile typology)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-1346	textile	A	1960	50	–23.92	43.8	AD 20–120
GrA-10195	skin	none	1590	50	–24.34	50.6	AD 425–535
GrA-14306	skin	none	1650	30	–24.25	46.5	AD 360–365, 385–430
GrA-14313	skin	AAA	1800	30	–23.81	45.9	AD 135–255, 305–315

21: Damendorf (1884)

Findspot: Ruchmoor, *Landkreis* Rendsburg-Eckernförde

Associated objects: fur cape and remains of two woollen garments

Repository: *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (inv. No. KS 5949)

Literature: [6], No. 225; [30], 16

Expected date: Iron Age (based on textile typology)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-9195	wool	alkaline	2250	50	–25.58	48.3	385–355, 315–205 BC
GrA-10156	wool	none	2760	50	–25.25	43.8	970–835 BC
GrA-10692	wool	AAA	2370	70	n/a	47.8	755–700, 540–385 BC
GrA-14403	wool	AAA	2350	35	–25.92	47.8	480–385 BC

22: Bunsöh (1890)

Findspot: Bunsöh, *Landkreis* Dithmarschen

Associated object(s): posts, woollen ‘necklace’

Repository: *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (KS without inv. No.)

Literature: [6], No. 272; [30], 16; [40], 93–95, 100

Expected date: Iron Age (based on textile typology)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-8026	skin	AAA	1100	80	−26.66	53.2	AD 785–840, 875–1020
GrA-10155	skin	none	1510	40	−23.30	47.5	AD 535–615
GrA-14318	skin	AAA	1480	30	n/a	n/a	AD 560–620

23: Damendorf Man (1900)

Findspot: Seemoor, *Landkreis* Rendsburg-Eckernförde

Associated objects: a woollen cloak, a pair of woollen breeches, two woollen leg wrappings, two leather belts, a pair of leather shoes

Repository: Archäologisches Landesmuseum Schloss Gottorf, Schleswig (inv. No. KS 10924)

Literature: [6], No. 311; [8], 24–27; [30], 17; [39], 146; [40], 49, 76–77, 81, 121, 125, 127, 193

Expected date: Iron Age (based on textile typology)

Radiocarbon result:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-507	wool	none	1780	45	−24.04	44.2	AD 135–335

24: Dätgen (1906)

Findspot: Grossen Moor, *Landkreis* Rendsburg-Eckernförde

Associated objects: a woollen cloak, a pair of woollen knee-length breeches and the remains of a woollen tunic and several other garments/accessories

Repository: Archäologisches Landesmuseum Schloss Gottorf, Schleswig (inv. No. KS 11919)

Literature: [6], No. 345; [30], 17–18; [40], 129

Expected date: Iron Age (based on textile typology)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-7509	wool	alkaline	1630	60	−24.86	47.8	AD 345–535
GrA-10192	wool	none	1530	40	−24.68	45.0	AD 440–600
GrA-15633	wool	AAA	1630	60	−24.18	44.0	AD 345–535

25: Röst Girl (1926)

Findspot: Röster Moor, *Landkreis* Dithmarschen

Associated objects: woollen cloak

Repository: body destroyed during WW II, cloak now in the *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (inv. No. KS 15609)

Literature: [6], No. 440; [30], 22; [40], 81–82, 89

Expected date: Iron Age (based on textile typology)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-9194	wool	alkaline	2100	50	−24.46	50.1	195–50 BC
GrA-13431	wool	none	1970	50	−23.66	47.7	40 BC–AD 80
GrA-14402	wool	AAA	2130	35	−24.16	45.0	200–95 BC

26: Damendorf Girl (1934)

Findspot: Ruchmoor, *Landkreis* Rendsburg-Eckernförde

Associated objects: short woollen skirt, fur cape, leather bowl, crooks and stones

Repository: Archäologisches Landesmuseum Schloss Gottorf, Schleswig (inv. No. KS 22412)

Literature: [6], No. 473; [30], 17; [39], 146; [40], 76–77, 81–82, 94–95, 103, 129, 167–168, 193

Expected date: Early Iron Age (based on palynological evidence)

Radiocarbon result(s):

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-506	hair	none	2700	45	−26.05	47.5	895–810 BC

27: Osterby Man (1948)Findspot: Köhlmoor, *Landkreis* Rendsburg-Eckernförde

Associated objects: fur cape

Repository: *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (KS without inv. No.)

Literature: [6], No. 632; [8], 28–31; [39], 147; [40], 6, 64, 76–77, 91, 145–146, 159, 193

Expected date: Roman Iron Age (Swabian knot mentioned in Tacitus' *Germania*, ch. 38, and depicted on Trajan's Column)

Radiocarbon result:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-822	hair	none	1895	30	–24.30	n/a	AD 75–130

28: Windeby Girl (1952)Findspot: Domlands Moor, *Landkreis* Rendsburg-Eckernförde

Associated objects: woollen band, fur cape, pottery sherds, a stone, a branch and several twigs

Repository: *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (inv. No. KS 22672)

Literature: [6], No. 658; [8], 32–47; [39], 147; [40], 16–18, 32, 55, 81–82, 93–94, 97–98, 100, 104, 112, 123, 131, 149, 164–165, 168–169

Expected date: 1st–2nd cent. AD (based on palynological evidence)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-10687	fur cape	AAA	2150	70	–25.00	50.4	255–65 BC
GrA-10689	fur cape	alkaline	2180	80	–26.43	39.4	365–115 BC
GrA-14175	fur cape	AAA	2010	50	–24.86	50.3	85 BC–AD 55
KIA-15123	bone		1971	28			
KIA-15911	wood		3122	31			
KIA-15912	cape hair		2168	31			

29: Dätgen Man (1959/1960)Findspot: Grosses Moor, *Landkreis* Rendsburg-Eckernförde

Associated objects: crooks, woollen thread

Repository: *Archäologisches Landesmuseum Schloss Gottorf*, Schleswig (inv. No. KS C410)

Literature: [6], No. 690–691; [2]; [40], 113–114, 135, 146, 159, 161–162, 165, 168

Expected date: mid-2nd cent. BC (based on three radiocarbon dates obtained for peat samples; KI 17: 2090 ± 60 BP; KI 86: 2040 ± 50 BP; KI 92: 2030 ± 60 BP)

Radiocarbon result:

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-8027	hair	AAA	1760	80	–21.06	n/a	AD 135–385

*Ireland***30: Tumbeagh (1998)**

Findspot: Tumbeagh Bog, Offaly County

Associated objects: wood

Repository: National Museum of Ireland, Dublin (inv. No. 98E452)

Literature: [41]

Expected date:

Radiocarbon result(s):

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-15627	skin	AAA	430	60	–23.04	46.4	AD 1420–1515, 1600–1615
GrA-15628	skin	none	790	60	–25.47	47.9	AD 1190–1285
GrA-14393	peat	AAA	765	35	–24.23	45.8	AD 1245–1285
GrA-14305	peat	none	880	30	–25.85	46.0	AD 1070–1080, 1125–1215
GrA-15314	wood	AAA	545	45	–27.88	45.0	AD 1325–1345, 1395–1430
GrA-14304	wood	none	345	30	–27.58	48.5	AD 1485–1525, 1560–1630

*The Netherlands***31: Yde Girl (1897)**

Findspot: Yde, municipality of Tynaarlo

Associated objects: woollen *sprang* band, woollen cloakRepository: *Drents Museum*, Assen (inv. No. N 1897/VI-1)

Literature: [6], No. 298; [37] 80–83, 98; [38]; [40], 31, 37, 60, 76–77, 82–83, 91, 129, 135–139, 150–153, 155–157, 161, 164–165, 191

Expected date: previous OxA date

Radiocarbon result(s):

Lab. No.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
OxA-1724	skin		1980	80			
GrA-9200	wool (<i>sprang</i>)	alkaline	2600	50	−24.86	48.4	830–760, 680–670 BC
GrA-10291	wool (<i>sprang</i>)	none	2110	40	−24.81	45.9	195–55 BC
GrA-14176	wool (<i>sprang</i>)	AAA	2015	30	−24.36	42.7	45 BC–AD 25
GrA-9199	wool (blanket)	alkaline	2100	50	−25.12	49.4	195–50 BC
GrA-10158	wool (blanket)	none	2030	40	−24.36	45.9	90 BC–AD 45
GrA-14178	wool (blanket)	AAA	1970	35	−24.36	45.9	15 BC–AD 70
GrA-9201	hair	AAA	1960	50	−20.12	45.6	20 BC–AD 120

32: Wijster Four (1901)

Findspot: Wijster, municipality of Midden-Drenthe

Associated objects: branches, a sleeved woollen jacket, a pair of woollen breeches, a leather jacket, a leather strap, 16 coins and a bronze cauldron

Repository: *Drents Museum*, Assen (inv. No. N 1901/VI-1; H1901-8 (clothing); H1903-28 (cauldron) and M1901-1-13 (coins))

Literature: [6], Nos. 322–325; [37], 61–62; [41]

Expected date: late 16th cent. (based on typology of the clothing); after AD 1585 (youngest coin)

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
GrA-13423	wool	none	430	40	−24.01	45.6	AD 1435–1485
GrA-14319	wool	AAA	370	30	n/a	n/a	AD 1455–1625
GrA-13429	skin	none	460	40	−23.73	49.1	AD 1415–1465
GrA-14392	skin	AAA	520	35	−23.59	43.1	AD 1405–1435
GrA-13428	bone ind.1	none	450	40	−22.65	44.3	AD 1425–1470
GrA-14397	bone ind.1	collagen	360	35	−21.66	42.6	AD 1475–1525, 1570–1625
GrA-13424	bone ind.3	none	1140	40	−25.40	50.2	AD 835–980
GrA-14405	bone ind.3	collagen	360	35	−20.70	43.0	AD 1475–1525, 1570–1625
GrA-13426	bone ind.4	none	380	40	−22.09	44.6	AD 1445–1625, 1595–1625
GrA-14407	bone ind.4	collagen	440	35	−21.63	42.7	AD 1435–1475
GrA-13427	wood	none	360	40	−26.89	46.2	AD 1475–1630
GrA-14323	peat	AAA	1215	30	n/a	n/a	AD 775–880
GrA-13439	peat	none	720	40	−27.81	45.2	AD 1265–1300
GrA-15620	peat	none	680	50	−28.27	41.1	AD 1280–1320, 1350–1385
GrN-23974	wood	AAA	500	45	−26.26	52.4	AD 1405–1440

33: Weerdinge Men (1904)

Findspot: Weerdingerveen, municipality of Emmen

Associated objects: none

Repository: *Drents Museum*, Assen (inv. No. N 1904/VII-2)

Literature: [6], Nos. 335–336; [37], 83–86, 98; [40], 51, 76–78, 97, 101–102, 133, 135, 137, 146, 155, 161, 178–180, 191

Expected date: previous OxA date

Radiocarbon results:

Lab. No.	Sample	Pre-treatment	¹⁴ C (BP)	Error (1σ)	δ ¹³ C (‰)	%C	Calibrated date (1σ)
OxA-1723	skin		1980	70			
GrA-12442	hair	AAA	2035	60	−22.01	43.3	115 BC–AD 50

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrA-13437	hair	none	1850	40	–22.03	42.6	AD 125–230
GrA-14310	skin	AAA	1990	40	–24.56	47.9	40 BC–AD 60
GrA-13436	skin	none	1950	40	–24.10	55.8	AD 5–120

34: Exloërmond Man (1914)

Findspot: Exloërveen, municipality of Borger-Odoorn

Associated objects: none

Repository: *Drents Museum*, Assen (inv. No. 1914/V-1)

Literature: [6], No. 391; [37], 86–89, 98; [40], 76–78, 114–115, 191

Expected date: previous OxA date

Radiocarbon result(s):

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
OxA-1725	skin		2280	75			
GrA-12449	hair	AAA	2210	60	–21.17	46.7	365–115 BC
GrA-13438	hair	none	2090	40	–20.32	45.5	165–50 BC

35: Emmer-Erfscheidenveen Man (1938)

Findspot: Emmer-Erfscheidenveen, municipality of Emmen

Associated objects: branches, fragments of woollen undergarment, shoe, fur cap, fur cape

Repository: *Drents Museum*, Assen (inv. No. 1962/II-207a)

Literature: [6], No. 502; [37]; [40]

Expected date: 14th–9th cent. BC (based on palynological evidence)

Radiocarbon result(s): previous GrN date

Lab. No.	Sample	Pre-treatment	^{14}C (BP)	Error (1σ)	$\delta^{13}\text{C}$ (‰)	%C	Calibrated date (1σ)
GrN-15459	wood	AAA	2980	35	–26.47	33.4	1285–1130 BC
GrA-19531	textile	AAA	3110	50	–24.74	42.2	1435–1315 BC
GrA-19532	hair	AAA	2995	45	–22.52	49.3	1315–1130 BC
GrA-19533	skin	AAA	3020	40	–24.11	48.3	1370–1135 BC

4. Discussion

In this section we will first discuss the ^{14}C dates obtained for the bog bodies in the order in which they are presented in the above catalogue. In the next section we will then discuss the results in terms of different sample materials.

4.1. The dates of the bog bodies

4.1.1. No. 1. *Elling Woman*, found in 1938, was previously dated by the ^{14}C laboratories in Copenhagen (conventional method) and Aarhus (AMS). The results are as follows: soft tissue- 2170 ± 55 BP (K-2876); fur cape— 2120 ± 55 BP (K-2877); hairs from fur cape— 2195 ± 40 BP (AAR-3415).

We performed additional tests on one of the capes of this body, which we analysed both with and without AAA pretreatment. The dates obtained for the samples that were not pretreated (GrA-10154 and 13434) are too young. For some unknown reason, two of the four AAA-treated samples (GrA-8012 and 14321) yielded results that deviate from those previously obtained in Denmark. It could be that these particular fragments were inadequately pretreated or the sampling was incorrectly performed. The GrA-14315 date is in full agree-

ment with the dates obtained in Denmark; the date obtained for GrA-15637 is older but acceptable with the 2σ criterion. The weighted average of these two GrA dates and the three published Danish dates is 2210 ± 20 BP, which yields a calibrated date of 355–205 cal BC for *Elling Woman*. Unfortunately, in spite of the precisely averaged ^{14}C date, a more precise calibrated date cannot be obtained due to a wiggle in the calibration curve.

4.1.2. No. 2. *Tollund Man* was found in 1950, not far from the spot where *Elling Woman* had come to light twelve years earlier. *Tollund Man* had previously been dated by the ^{14}C laboratories in Copenhagen (conventional method) and Aarhus (AMS). The results were as follows: soft tissue: 2150 ± 75 BP and 2260 ± 75 BP (K-2814A); another soft tissue sample: 2110 ± 75 BP and 2140 ± 55 BP (K-2814B); bone- 2345 ± 40 BP (AAR-3328).

We tested soft tissue with and without AAA pretreatment. We obtained two results for the pretreated samples which differ from the previous results, but are acceptable with the 2σ criterion: 1950 ± 80 BP (GrA-8028) and 2290 ± 30 BP (GrA-14179). The weighted average of the 2 GrA measurements and the five Danish

measurements is 2240 ± 20 BP, which yields a calibrated date of 375–210 cal BC for Tollund Man. As in the case of Elling Woman, a more precise calibrated date cannot be given because of a wiggle in the calibration curve. Nevertheless, Tollund Man and Elling Woman appear to be contemporary.

We would like to add that a wooden trackway found close to the two Danish bog bodies has also been dated using the conventional method. The results of two measurements are 2490 ± 50 (GrN-22994) and 2520 ± 70 (GrN-23165); they yield an average of 2500 ± 40 BP, which coincides with the “Hallstatt plateau”, a flat part of the calibration curve. The calibrated age range is therefore very large: 780–520 cal BC. We nevertheless conclude that the wood from the trackway is a few (at least two) centuries older than the bog bodies.

4.1.3. No. 3. Bareler Moor Girl, found in 1784, was cut into pieces shortly after the body’s discovery. Various parts of the body were sent to institutes all over Europe. Only part of the skin of the right chest survives. This bog body had never been dated. We dated a sample of the skin after full (AAA) pretreatment. The result is 1710 ± 50 BP (GrA-9153). The calibrated age range is cal AD 260–395, which means that Bareler Moor Girl lived in the Roman period.

4.1.4. No. 4. The Marx-Etzel body, discovered in 1817, was the first bog body to be associated with Tacitus’ *Germania*. Schlabow [30] dated the clothing to the *Eisenzeit*, i.e. the pre-Roman/Roman Iron Age. We dated two wool samples from the tunic and breeches. The date obtained for the alkaline extract is younger than that obtained for the fully pretreated sample; we consider the latter date the more reliable. The ^{14}C date of this textile is 1970 ± 70 BP (GrA-12418). The calibrated age range is cal AD 45–125.

4.1.5. No. 5. The Marx-Stapelstein body, found in 1861, was on the basis of its clothing assumed to date from the pre-Roman Iron Age. We dated three pieces of wool. Surprisingly, one piece of wool sent to us by the museum proved to be subrecent (GrA-9155 and 10289). This material probably stems from the time of the body’s discovery. The non-pretreated samples yielded older dates than the AAA-treated samples. Only a non-pretreated result could be obtained for one sample (No. 3). The AAA-treated sample No. 2 yielded a date of 1780 ± 50 BP (GrA-12425). This we consider the ^{14}C date of this bog body. The calibrated age range is cal AD 135–385.

4.1.6. No. 6. Oberaltendorf Man, who came to light in 1895, has always been assumed to date from the Roman Iron Age (on the basis of silver ornaments). We dated a sample of hair from this body to 1750 ± 50 BP (GrA-

1352). A second sample, consisting of wool from the clothing, yielded a date of 1690 ± 50 BP (GrA-1351). Because of the delicate nature of the materials, we pretreated the samples only partially (only step A of the pretreatment procedure). The two results are in excellent agreement, and we therefore consider these dates to be reliable. The calibrated date obtained for the average of the two measurements is cal AD 260–380, which agrees with the expected date.

4.1.7. No. 7. Neu Versen Man, better known as *Roter Franz*, was dated to the Roman Iron Age on the basis of the results of pollen analysis. We dated two samples of hair from this body (GrA-1532 and 16196), one after AAA pretreatment and one without pretreatment; the results agree within the error range. The calibrated age range obtained for the fully pretreated sample, and therefore for the body of *Roter Franz*, is cal AD 135–385.

4.1.8. No. 8. Brammer Man, found in 1903, was always assumed to be a prehistoric bog body. As this body was destroyed during WWII, we had little hope of ever being able to prove this—until one of us (WvdS) came across a tuft of hair from the body among the finds of the collection of the *Moor- und Fehnmuseum* in Elisabethfehn. Alfred Dieck had presented the hair to the *Museumsleiter*. We dated a sample of hair from this tuft. The result is 390 ± 60 BP (GrA-8014), obtained for a fully (AAA) pretreated sample. We also analysed a sample without pretreatment and obtained a slightly older date of 540 ± 50 BP (GrA-12208). From the results of the analysis of the fully pretreated sample we infer that the body dates from cal AD 1440–1520 or 1585–1625.

4.1.9. No. 9. The clothing of Bernuthsfeld Man, found in 1907, was dated to the Middle Ages on the basis of typological criteria by the textile expert of the *Landesmuseum* in Schleswig. We dated a sample of hair from the body. The result is 1290 ± 45 BP (GrA-782). Because of the delicate nature of the sample we omitted pretreatment. The calibrated date (cal AD 680–775) nevertheless corresponds to the expected date.

4.1.10. No. 10. Kayhausen Boy, found in 1922, was 8–14 years old when he met a violent death. The body was dated to the first half of the Roman Iron Age on the basis of the results of pollen analysis. We dated bone, hair and wool from this bog body. The bone collagen was found to date from 2360 ± 40 BP (GrA-14404), the hair from 2160 ± 50 BP (GrA-1393) and the wool of the clothing from 2240 ± 30 BP (GrA-14314). We obtained one deviating ^{14}C date for a second bone sample (GrA-9150); this particular piece of bone however had a rather low carbon content, so we consider this result to be unreliable. Calibration of the resulting ^{14}C date of c.

2200 BP yields inaccurate results because of the Hallstatt plateau in the calibration curve. The result spans 2–3 centuries. The ^{14}C dates are older than the dates assumed on the basis of palynological evidence.

Surprisingly, part of the wool sample that was not pretreated yielded a recent date.

4.1.11. No. 11. Jühdenerfeld Man, found in 1934, was assumed to date from 400–0 BC on the basis of palynological evidence. We measured a skin and a hair sample. The result obtained for the skin sample is 2090 ± 50 BP (GrA-9149). Calibrated, this corresponds to 170–45 cal BC. The date obtained for the hair sample, which was only partially pretreated (A pretreatment only), is slightly older: 1975 ± 50 BP (GrA-1325). Both dates average to 2030 ± 35 BP, calibrated: 90–80 cal BC or 55 cal BC–cal AD 25.

4.1.12. No. 12. Husbäke Man, discovered in 1936, was assumed to date from between 600 and 200 BC on the basis of palynological evidence. A skin sample yielded a date of 2480 ± 50 BP (GrA-9148). Unfortunately, this result coincides with the ‘Hallstatt plateau’ in the ^{14}C calibration curve; the calibrated time range is therefore large, 765–520 cal BC. The ^{14}C date nevertheless closely corresponds to the date based on palynological evidence. This sample underwent full pretreatment (AAA). We later analysed another piece of skin without pretreatment and obtained a slightly younger result: 2370 ± 50 BP (GrA-10153). In this case the hair samples yielded much younger results (GrA-15631, 1350).

The hair sample derives from Dieck’s collection. This source could very well be unreliable.

4.1.13. No. 13. The Hunteburg Foot was found in 1938. The foot is clad in a shoe. The shoe has been dated to the 13th–mid-14th century on typological grounds. We measured a sample of skin and obtained a date of 750 ± 70 BP (GrA-914). The calibrated age range is cal AD 1215–1300. The sample was very delicate, so we restricted pretreatment to washing with hot water.

4.1.14. No. 14. The skeleton of Sedelsberger Dose Man was found in 1939. The body was dated to the Middle Ages (11th–12th century) on the basis of palynological evidence. We were able to extract collagen from a bone sample. The ^{14}C date is 900 ± 45 BP (GrA-9151), corresponding to a calibrated age range of cal AD 1050–1200.

4.1.15. No. 15. Neu England Man, found in 1941, was dated to between AD 100 and 400 on the basis of palynological evidence. A fully pretreated skin sample yielded a date of 1800 ± 50 BP (GrA-9196). A second sample, consisting of hair, was found to date from 1775 ± 50 BP (GrA-1349). Since the two results are in excellent agreement we consider the dates to be reliable.

The calibrated date obtained for the average of the two measurements (1790 ± 35 BP) is cal AD 140–320. This is also consistent with the dates based on palynological evidence.

4.1.16. No. 16. The Hunteburg Men were unearthed in 1949. The find’s antiquity was estimated on the basis of palynological evidence (5th–1st century BC) and the typology of the two cloaks (*Eisenzeit*, i.e. pre-Roman/Roman Iron Age). We dated a hair sample from Hunteburg-I to 1710 ± 70 BP (GrA-16197). The calibrated age range is cal AD 245–415. The sample that was not pretreated (GrA-1535) yielded the same range (within the error range).

4.1.17. No. 17. The Hunteburg III body was also discovered in 1949, shortly after the bodies referred to under No. 16. The find never received any attention in the literature. We dated bone from which collagen could be extracted. The ^{14}C date obtained for the collagen fraction is 1975 ± 45 BP (GrA-508). The calibrated age range is 40 cal BC–cal AD 75. Analysis of a sample of residue (GrA-509) yielded the same age (within the error range).

4.1.18. No. 18. The Bentstreek Foot, found in 1955, consists of a shoe containing a foot attached to the lower part of a leg; the shoe also contained a fragment of textile. The find was dated to the Late Bronze Age (10th–9th cent. BC) on the basis of palynological evidence. Triplicate radiocarbon dating of the leather however yielded an average date of 1875 ± 25 BP (GrA-9156, 14311, 12416). The calibrated results are cal AD 80–135, 160–170 and 195–210. These three dates were obtained for AAA-pretreated samples. The dates obtained without pretreatment are significantly younger (GrA-10288 and 14681). A hair found on the body was found to be of recent date (GrA-12291; ^{14}C activity $123.8 \pm 0.7\%$), so is apparently not associated with the bog body.

4.1.19. No. 19. All that remains of the body of Johann Spieker, a hawker who died on Goldenstedter Moor in 1828, are a few hairs found on his clothing. We dated a tiny fragment of wood and some hair and textile found during the excavation in 1978. The ^{14}C dates obtained for the samples, which were all AAA-pretreated, are 155 ± 40 BP (GrA-19543), 175 ± 40 BP (GrA-19544) and 225 ± 40 BP (GrA-19547). The weighted average of these dates is 185 ± 25 BP. Calibration yields multiple results due to the large wiggles in the ^{14}C calibration curve, but all possible dates are consistent with the find’s historical age.

4.1.20. No. 20. Rendswühren Man came to light in 1871. The body was dated to the pre-Roman/Roman Iron Age on the basis of the clothing. We dated a skin sample to

1800±30 BP (GrA-14313). A second sample, consisting of textile from the clothing, yielded an earlier date of 1960±50 BP (GrA-1346). The textile sample was very delicate, so we restricted pretreatment to step A. The skin sample we subjected to full AAA pretreatment. The results obtained for the non-pretreated skin samples are both too young. The calibrated age ranges of the skin are cal AD 135–255 and 305–315.

4.1.21. No. 21. All that remains of *Damendorf Woman*(?), discovered in 1884, is the clothing. The garments were dated to the pre-Roman/Roman Iron Age. We dated wool in duplicate (GrA-10692 and 14403) after subjecting both samples to full pretreatment (AAA). A non-pretreated sample yielded a date that was too old, while the alkaline fraction yielded a date that was slightly younger than that obtained for the fully pretreated samples.

The average of the two measurements is 2355±30 BP, corresponding to a calibrated age range of 410–390 cal BC. This happens to be a very precise range because the averaged ¹⁴C date coincides with a steep slope in the calibration curve.

4.1.22. No. 22. Little remains of the *Bunsoh body*, which was found in 1890. The woollen ‘necklace’ found with the body is assumed to date from the pre-Roman/Roman Iron Age. We dated a skin sample. Our first attempt resulted in a yield of only 1%. The very delicate sample had evidently been too rigorously pretreated. The resulting ¹⁴C date, 1100±80 BP (GrA-8026), we therefore consider to be unreliable. In our next attempt we conducted the chemical pretreatment at room temperature. A fully (AAA) pretreated sample yielded a result of 1480±30 BP (GrA-14318). We obtained the same result within the error range for an untreated sample (1510±40 BP; GrA-10155). The calibrated age range is cal AD 560–620. This does not conflict with the assumed date of the woollen ‘necklace’.

4.1.23. No. 23. *Damendorf Man* was found in 1900. His clothing was dated to the pre-Roman/Roman Iron Age. We dated a wool sample to 1780±45 BP (GrA-507), corresponding to a calibrated age range of cal AD 135–335. Pretreatment was again restricted to step A because of the delicate nature of the material, so there is a possibility that some residual contamination interfered with the determination.

4.1.24. No. 24. The *Dätgen bog body* that was found in 1906 has not survived. The clothing, however, has. It was dated to the pre-Roman/Roman Iron Age. We dated a wool sample. The fully (AAA) pretreated sample yielded a ¹⁴C date of 1630±60 BP (GrA-15633), corresponding to a calibrated age range of cal AD 345–535. The alkaline fraction yielded the same result within the

error range; non-pretreated wool yielded a slightly younger date. This may be regarded as evidence confirming the reliability of the pretreatment procedure (i.e. the removal of all interfering contaminants).

4.1.25. No. 25. *Röst Girl* was discovered in 1926; the body was destroyed during the Second Worldwar. The woollen cloak found in association with the body fortunately survived. It was dated to the pre-Roman/Roman Iron Age. The fully (AAA) pretreated wool sample yielded a ¹⁴C date of 2130±35 BP (GrA-14402), corresponding to a calibrated age range of 200–95 cal BC. As in the case of the previous bog body (*Dätgen*, No. 24), the alkaline fraction yielded the same result within the error range; non-pretreated wool yielded a slightly younger result.

4.1.26. No. 26. *Damendorf Girl*, found in 1934, was dated to the early pre-Roman Iron Age on the basis of palynological evidence. We dated a hair sample to 2700±45 BP (GrA-506), which corresponds to a calibrated age range of 895–810 cal BC (Late Bronze Age). The sample could not be pretreated because of the delicate nature of the material, so contaminants may have interfered with the determination, making the reliability of the date questionable.

4.1.27. No. 27. The head of *Osterby Man* was found in 1948. It was wrapped in a deerskin cape. The man’s hair was tied in a so-called ‘Swabian knot’, known from Tacitus’ *Germania* (written c. AD 98) and representations in Roman sculpture. This led to the assumption that the head is around 2000 years old. We dated a hair sample to 1895±30 BP (GrA-822). Calibrated, this ¹⁴C date indeed corresponds to the expected date (cal AD 75–130), but the sample could not be pretreated due to its delicate nature. Despite the agreement with the expected date, the date’s reliability is questionable.

4.1.28. No. 28. *Windeby Girl*, whose body was found in 1952, died at an age of about 14. The body was dated to the first part of the Roman Iron Age on the basis of palynological evidence. We first dated wood associated with this bog body. The result, 6540±70 BP (GrN-20546), was clearly influenced by some substance used to preserve the wood (some wood associated with a bog body found close to *Windeby Girl*—that of *Windeby Man*—was likewise found to be much too old: 7130±70 BP; GrN-20547). A second effort, for which we were granted a fragment of the fur cape, proved more successful. We dated two AAA-pretreated samples (GrA-10687 and 14175) and obtained an average date of 2060±40 BP. Calibrated, this corresponds to 150–135 and 115–0 cal BC. The alkaline fraction yielded a similar result. The bog body was at a later stage also ¹⁴C dated in Kiel, Germany [9]. The cape hair result (KIA-15912)



Fig. 2. “Yde girl”, the body of a strangled 16-year-old girl found near Yde, the Netherlands, in 1897. Note the cord used to strangle the girl visible around her neck. Drents Museum, Assen.

is consistent with our measurements. Bone from the body (KIA-15123) yielded a younger date. An associated wood sample (KIA-15911) yielded a date in the Bronze Age, which is of course too old.

4.1.29. No. 29. Dätgen Man comprises the remains of a decapitated man; the body was found in 1959, the head—with hair tied in a Swabian knot—in 1960. Radiocarbon dates obtained for peat samples from beneath and above the human remains led to the conclusion that the body was deposited in the peat in the mid-2nd century BC (the average of three ^{14}C dates is 2060 ± 35 BP). We dated a fully pretreated hair sample to 1760 ± 80 BP (GrA-8027), which yields a calibrated date of cal AD 135–385.

4.1.30. No. 30. The Tumbeagh bog body, found in 1998, is the most recently discovered bog body. Only a few parts of the body survived impact with a mechanical excavator.

We dated the bog body to 430 ± 60 BP (GrA-15627). The same date was obtained for a skin sample from the right leg after AAA pretreatment. We also analysed non-pretreated skin and obtained a much earlier date of 790 ± 60 BP (GrA-15628). The latter date however closely corresponds to a radiocarbon date obtained for a peat sample from immediately beneath the calf of the left leg after full AAA pretreatment, i.e. 765 ± 35 BP (GrA-14393). The result obtained without pretreatment is a century older (880 ± 30 BP; GrA-14305). Some samples of brushwood stakes found under the lower right thigh were also analysed with and without pretreatment. The date obtained for the fully pretreated wood is 545 ± 45 BP (GrA-15314); without pretreatment the wood yielded a younger date (345 ± 30 BP; GrA-14304).

In such cases full pretreatment of skin samples is evidently necessary to remove older contaminants from the peat.

4.1.31. No. 31. Yde Girl is the body of a 16-year-old girl that was found in 1897 (Fig. 2). The girl died through strangulation with a woollen band woven with the *sprang* technique. This bog body acquired worldwide fame thanks to the reconstruction of the girl's head [38].

The girl's body was first ^{14}C dated in Oxford, yielding a result of 1980 ± 80 BP (OxA-1724). When the Groningen AMS facility became operational, this body was one of the first to be subjected to more extensive radiocarbon dating. The Oxford date closely corresponds to the following dates obtained in Groningen: hair from the body— 1960 ± 50 BP (GrA-9201), wool from the girl's cloak— 1970 ± 35 BP (GrA-14178) and wool from the *sprang* band: 2015 ± 30 BP (GrA-14176). All the dates overlap within the error range. The weighted average of the four dates is 1990 ± 20 BP, a high-precision result. Calibration of this date with INTCAL98 [32] yields less precise results because of the wiggles in this part of the calibration curve. The calibrated result, which is shown in Fig. 3, implies that Yde Girl died between 40 cal BC and cal AD 50. The four samples were all subjected to standard AAA pretreatment. We also analysed non-pretreated wool samples and the alkaline fraction. The latter samples all yielded older dates as a result of contamination with humic substances from the peat.

4.1.32. No. 32. The Wijster Four were discovered in 1901. Only a few remains of the four bodies have survived. Among the surviving remains is a hand. All the individuals died before they had reached the age of 25.

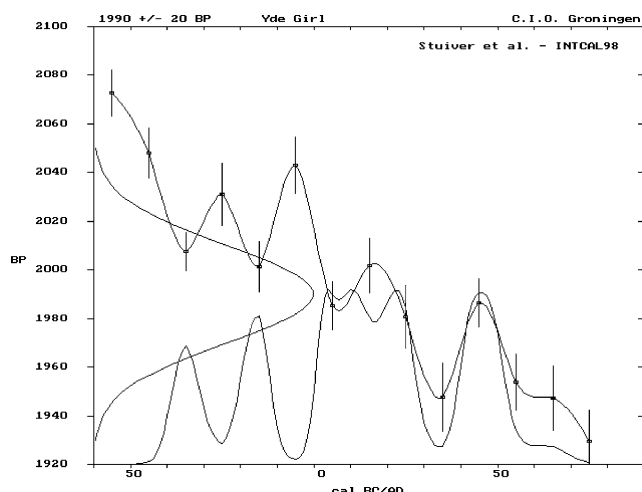


Fig. 3. Calibrated result obtained for the bog body known as Yde Girl (the Netherlands). The average of four dates, 1990 ± 20 BP, was calibrated using INTCAL98 [32]. The calibrated date is 40 cal BC–cal AD 50.

The find also includes leather and textile clothing, a bronze cauldron and coins. The youngest coin dates from 1585. The bodies' association with objects that can be independently dated to the late 16th century makes this find of particular interest.

Collagen could be extracted from bones of three of the individuals following standard procedures [21]. The dates obtained for the collagen are 360 ± 35 BP (GrA-13424), 360 ± 35 BP (GrA-14405) and 440 ± 35 BP (GrA-14407). As these three dates relate to different individuals we did not average them. We also analysed these samples without pretreatment; only one yielded a date that is significantly earlier than that obtained for the collagen sample (GrA-13424). Skin (from the hand) and clothing were also dated, yielding 520 ± 35 BP (GrA-14392) and 430 ± 40 BP (GrA-13423), respectively.

So the radiocarbon dates obtained for the Wijster find correspond closely to the date of c. cal AD 1600 based on the coin finds.

Associated wood samples were dated to 360 ± 40 BP (GrA-13427) and 500 ± 45 BP (GrN-23974). A peat sample was dated to 1215 ± 30 BP (GrA-14323). The latter sample, of peat adhering to the hand, is hence much older—8th–9th century—than the body. This need not cause surprise as the bodies may well have been buried in a pit and hence have been in contact with older peat.

4.1.33. No. 33. The *Weerdinge Men* (see Fig. 1) were found in 1904. They were first dated in Oxford, resulting in a date of 1980 ± 70 BP (OxA-1723). We obtained ^{14}C dates for skin and hair samples from one of the bodies. The dates obtained for the AAA-pretreated samples are 2035 ± 60 BP (GrA-12442, hair) and 1990 ± 40 BP (GrA-

14310, skin). The weighted average of the two dates is 2000 ± 35 BP, which corresponds to a calibrated age range of 40 cal BC–cal AD 50.

4.1.34. No. 34. The body of *Exloërmond Man* was found in 1914. A skin sample was previously dated to 2280 ± 75 BP (OxA-1725) in Oxford. This is in excellent agreement with the date we obtained for a sample of hair: 2210 ± 60 BP (GrA-12449).

The sample underwent full (AAA) pretreatment. The calibrated age range corresponds to 365–115 cal BC.

4.1.35. No. 35. *Emmer-Erfseidenveen Man*, found in 1938, is the oldest bog body with soft tissue preserved in the Netherlands. The body was found in association with sticks and several pieces of clothing. Pollen analysis suggested that the body dated from the 14th–9th century BC. One of the sticks was with the conventional method dated to 2980 ± 35 BP (GrN-15459). The dates we have now obtained for samples of textile, hair and skin are 3110 ± 50 BP (GrA-19531), 2995 ± 45 BP (GrA-19532) and 3020 ± 40 BP (GrA-19533), respectively.

All four samples underwent full (AAA) pretreatment. The measured results are within 2σ from each other. The averaged result of the four ^{14}C dates is 3015 ± 20 BP. Unfortunately, calibration of this result yields a far less precise outcome: the calibrated age ranges are 1370–1365, 1315–1260 and 1235–1215 cal BC.

4.2. Comparison of sample materials

4.2.1. Hair. We analysed samples of hair associated with a total of 18 bog bodies. Depending on the quality and available quantity of material, we subjected the samples to standard, full AAA pretreatment, step A of the pretreatment procedure (delicate samples) or no pretreatment other than cleaning with hot water.

The ^{14}C hair dates obtained for bog bodies Nos. 6 (Oberaltendorf), 19 (Goldenstedt), 31 (Yde), 33 (Weerdinge), 34 (Exloërmond) and 35 (Emmer-Erfseidenveen) are considered to be reliable. Sample No. 6 underwent only step A of the pretreatment procedure, all the others were subjected to the full procedure. By “reliable” we mean that the dates obtained are comparable with ^{14}C dates obtained for other datable sample materials such as skin or textile. The ^{14}C hair dates obtained for bog bodies Nos. 10 (Kayhausen), 11 (Jühdenerfeld) and 13 (Hunteburg) are reasonably reliable in that they are similar to dates obtained for other datable materials. But these hair samples were very delicate and underwent only step A of the pretreatment procedure, which means that any residual contaminants may have interfered with the determination.

The ^{14}C dates obtained for hairs from bog bodies Nos. 7 (Neu Versen), 8 (Brammer), 15 (Neu England), 16 (Hunteburg) and 29 (Dätgen) also seem to be reasonably reliable, but we had no other samples to

enable comparison. These samples all underwent full AAA pretreatment.

The hairs from bog bodies Nos. 9 (Bernuthsfeld), 26 (Damendorf) and 27 (Osterby) were very delicate, precluding pretreatment, so we are unable to say whether the ^{14}C dates obtained for these samples are correct.

The results obtained for hair from bog body No. 12 (Husbäke) are questionable. Both an AAA-pretreated sample and a sample subjected to A treatment only yielded dates that are much later than that obtained for a sample of skin from this body.

In some cases (bog bodies Nos. 7 (Neu Versen), 8 (Brammer), 17 (Hunteburg), 33 (Weerdinge) and 34 (Exloërmond)) we also dated non-pretreated samples to check the dates obtained for AAA-pretreated samples of hair from the bodies. In three cases the same ^{14}C dates were obtained for both samples and in two cases the non-pretreated sample was found to be older.

As part of our experiment we also dated some other hair finds from bogs (not associated with bog body finds). In the first place we analysed a sample of human hair that was found on *Molberger Dose* (Landkreis Cloppenburg, Lower Saxony) in 1886 ([16], 21–23). After AAA treatment, this hair yielded a ^{14}C date of 1840 ± 60 BP (GrA-12499); a non-pretreated sample yielded 1890 ± 70 BP (GrA-12498).

We also dated a horsetail that is said to have been found near Valthe on *Bourtanger Moor* (municipality of Emmen, the Netherlands; [39], 188). Fully pretreated hair samples measured in duplicate yielded dates of 270 ± 40 BP (GrA-9170) and 300 ± 50 BP (GrA-15636). A non-pretreated sample yielded a much older date of 1810 ± 40 BP (GrA-10290). This difference must be attributable to older peat present in the sample.

Our general conclusion is that bog bodies can indeed be ^{14}C dated via hair samples. In general, full AAA pretreatment is recommended. In the case of delicate materials step A of the pretreatment procedure may suffice; reliable ^{14}C dates are obtained in all cases. In some cases reasonable to good results may also be obtained for non-pretreated samples, but this cannot be guaranteed.

4.2.2. Clothing (wool, textile, fur). We dated clothing samples associated with a total of 14 bog bodies. Depending on the quality and available quantity of material, we subjected the samples to standard, full AAA pretreatment, step A of the pretreatment procedure (delicate samples) or no pretreatment other than cleaning with hot water.

The ^{14}C textile dates obtained after full AAA pretreatment are all considered to be reliable. The dates concerned relate to bog bodies Nos. 4 (Marx-Etzel), 5 (Marx-Stapelstein), 10 (Kayhausen), 19 (Goldenstedt), 21 (Damendorf), 24 (Dätgen), 25 (Röst), 28 (Windeby), 31 (Yde) and 32 (Wijster). The dates are assumed to be

reliable because they coincide with dates based on textile typology (mostly Iron Age) and/or similar dates obtained for samples of other materials associated with the bog body.

The date obtained for the fur cape of body No. 1 (Elling) is also assumed to be reliable on the basis of comparisons with dates of other materials and dates obtained by other laboratories. Some ^{14}C dates were found to deviate for an unknown reason. The differences are presumably attributable to contaminants not removed in the pretreatment.

Two ^{14}C dates were obtained for textile samples that underwent only step A of the pretreatment procedure. These dates are also considered to be reliable on the basis of typological features of associated ornaments (bog body No. 6, Oberaltendorf) or textile (bog body No. 20, Rendswühren).

In a few cases (Nos. 24, 25 and 28) we also dated the alkaline fraction. The dates obtained were the same as those obtained for the fully treated fractions within the error range; slightly younger results were obtained for non-pretreated wool. This may be regarded as evidence confirming the reliability of the pretreatment procedure (i.e. the complete removal of contaminants).

One wool sample associated with bog body No. 23 (Damendorf) was dated without proper pretreatment. Whether the outcome is reliable we do not know; Iron Age textile typology suggests that the ^{14}C date is reasonable.

Our general conclusion is that bog bodies can be ^{14}C dated using samples of clothing (textile, wool). In general, full AAA pretreatment is recommended. In the case of delicate materials step A of the pretreatment procedure yields reliable ^{14}C dates. Non-pretreated samples may also yield reliable results, but this cannot be guaranteed.

We should add that textile is particularly suitable for ^{14}C dating because it has a short life [42].

4.2.3. Skin. We dated samples of skin from a total of twelve bog bodies. All the samples were fully pretreated according to the AAA procedure. The ^{14}C dates obtained for the following ten samples are considered to be reliable: bog bodies Nos. 2 (Tollund), 3 (Bareler Moor), 11 (Jühdenerfeld), 13 (Hunteburg), 15 (Neu England), 22 (Bunsöh), 30 (Tumbeagh), 32 (Wijster), 33 (Weerdinge) and 35 (Emmer-Erfscheidenveen). These dates are assumed to be reliable because they overlap with ^{14}C dates obtained for samples of other materials, dates obtained by other laboratories or dates based on typological evidence. In some cases non-pretreated samples yielded the same ^{14}C dates (Nos. 22, 32 and 33).

The results obtained for two bog bodies (No. 12, Husbäke, and No. 20, Rendswühren) are problematic. The skin date obtained for bog body No. 12 (Husbäke) is much older than the hair date, while both samples were

subjected to AAA pretreatment. Non-pretreated skin yielded the same ^{14}C date as fully pretreated skin. And the skin date obtained for bog body No. 20 (Rendswühren) is much younger than the textile date. In this case non-pretreated skin yielded a ^{14}C date that is too young.

We conclude that bog body skin is also suitable for ^{14}C dating. Full pretreatment (AAA) of samples usually yields reliable ^{14}C dates.

4.2.4. Bone. Bog body finds only rarely include bone. Bone is usually dissolved by chemical processes in the peat. We analysed bone samples from four bog bodies: Nos. 10 (Kayhausen), 14 (Sedelsberger Dose), 17 (Hunteburg) and 32 (Wijster). In all cases, bone collagen was extracted as the datable fraction.

The bone date obtained for bog body No. 10 (Kayhausen) is slightly older than the dates obtained for samples of wool (after AAA pretreatment) and hair (after step A only). The date obtained for a second piece of bone is considered to be unreliable on the basis of the $\delta^{13}\text{C}$ and carbon content values of the collagen.

The ^{14}C dates obtained in the other cases are considered to be reliable. In the case of bog body No. 17 (Hunteburg) we also dated the residue fraction and obtained the same date as for the collagen fraction. This can be seen to confirm that any contaminants present in the original sample were adequately removed in the pretreatment.

No. 32 (Wijster) is a find consisting of four bodies which are only a few centuries old. We dated bones of three of the individuals. Unreliable results were obtained in trial dating without pretreatment.

We conclude that bog body bones, when available, yield good ^{14}C dates after proper pretreatment of the samples. The $\delta^{13}\text{C}$ and carbon content values are indicative of the reliability of the results.

4.2.5. Leather. Leather samples associated with bog body finds may come from shoes, belts, etc. and are relatively rare. We used leather samples to date one of the bog bodies, No. 18 (Bentstreek). Triplicate measurements clearly showed that such samples require full pretreatment (AAA). Radiocarbon results obtained for non-pretreated samples were far too young.

4.2.6. Peat and wood. Peat and wood are both commonly used for ^{14}C dating. A complicating factor in the case of bog bodies, however, is that it is often not clear to what extent the body is associated with its peat context. We will nevertheless report some of the results we obtained for peat and wood for the sake of completeness.

We obtained ^{14}C dates for peat samples associated with bog bodies Nos. 30 (Tumbeagh) and 32 (Wijster). In both cases the peat was found to be older than the bog body buried in it. This is indeed logical and confirms

previously proposed theories—see e.g. discussions of Lindow Man [3]. Peat samples yield reliable ^{14}C dates only after full AAA pretreatment.

Over the years, the Groningen Radiocarbon laboratory has obtained broad experience in dating wood finds from peat bogs. Wood associated with bog bodies is not very common; this is unfortunate, because wood can be dated very reliably. We obtained ^{14}C dates for wood associated with bog bodies Nos. 19 (Goldenstedt), 30 (Tumbeagh), 32 (Wijster) and 35 (Emmer-Erfscheidenveen). The dates are all reasonable to good (in terms of the extent to which they correspond to the ^{14}C dates obtained for the samples of body parts). From our wood bog finds we conclude that pretreatment is essential for obtaining reliable results in the case of wood. The pretreatment may be either the standard AAA procedure or it may involve the preparation of cellulose from the wood.

4.3. The stable isotope ^{13}C

In conclusion, we will discuss the different sample materials in terms of the stable isotope ^{13}C . All radiocarbon dates are reported in years BP, which by definition includes correction for isotopic fractionation [26]. This is a correction based on the stable isotope ^{13}C for mass-dependent effects occurring both in nature and in laboratory procedures. The ^{13}C content is calculated in $\delta^{13}\text{C}$, which is defined as the relative deviation of the $^{13}\text{C}/^{12}\text{C}$ ratio of the sample from that of a standard, expressed in per mille. By convention, all ^{14}C dates are corrected to $\delta^{13}\text{C} = -25\text{‰}$ [23]. Apart from their use as correction factors for isotope fractionation, $\delta^{13}\text{C}$ values also provide important information on matters such as the quality and origin (and possible contamination) of sample materials. The $\delta^{13}\text{C}$ values for wood samples generally range from -23‰ to -27‰ , those for peat from -25‰ to -29‰ and those for human bone collagen from -19‰ to -21‰ [24]. Hair and skin yield collagen-like $\delta^{13}\text{C}$ values.

Fig. 4 presents a survey of the $\delta^{13}\text{C}$ values obtained for the bog finds discussed in this paper (bodies and associated samples). The values have been plotted in the categories skin, hair, wool, textile, bone, wood, peat and leather. The samples' carbon contents (%C) are given in Fig. 4b. For a ^{14}C date to be considered reliable, the average carbon content should be approximately 40% in the case of hair and bone, approximately 43% in the case of wool and textile and approximately 48% in the case of skin. The data presented in Fig. 4 include only Groningen (GrA) measurements.

On the whole, the $\delta^{13}\text{C}$ values obtained may be considered to be reasonably reliable, especially in view of the nature and origin of the samples. A few outlying values imply the presence of residual contaminants; the more negative values in particular may be attributable to incomplete removal of peat components. Note that Fig.

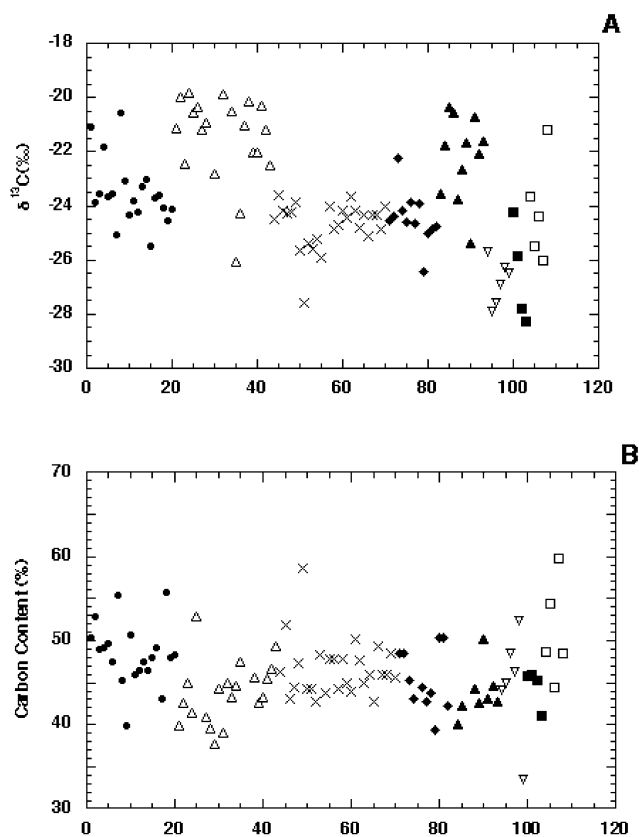


Fig. 4. Plots indicating $\delta^{13}\text{C}$ (a) and carbon content (b) values obtained for bog body samples. *● skin, Δ hair, \times wool, \blacklozenge textile, \blacktriangle bone, ∇ wood, \blacksquare peat, \square leather. The numbers along the abscissa are arbitrary sample numbers.

4 presents all the available data (i.e. data obtained for both pretreated and non-pretreated samples). As discussed above, we used both the $\delta^{13}\text{C}$ and $\%C$ values in assessing the reliability of the ^{14}C dates obtained.

5. Conclusion

We have dated a large, unique collection of bog body finds by means of the ^{14}C method. Our catalogue consists of 40 bog bodies from 35 findspots and more than 100 AMS dates. Our main conclusion is that bog bodies usually yield reliable ^{14}C dates. This is an important conclusion because it has hitherto always been generally assumed—mainly on the basis of unresolved dating problems concerning Lindow Man—that bog bodies cannot be reliably dated via this method. The majority of the bog bodies from northwest Germany and the northeastern part of the Netherlands were found to date from the Roman period.

In our research we tested a variety of dating materials and pretreatment procedures.

We dated wood, fur and textile as materials associated with bog body finds. Wood is preferred for ^{14}C

dating, providing it is unambiguously associated with the bog body. We do realise however that wood finds are quite exceptional. Textile is also suitable for ^{14}C dating because it is a short-lived material. We observed no differences between leather, fur and hair.

We dated bone, skin and hair taken from the bodies themselves as direct bog body samples. The datable fraction in these cases is collagen. Bone finds are rare, and even when bone is available it does not always contain collagen. Hair and skin samples both yield reliable ^{14}C dates. One of the basic rules in radiocarbon dating applies to bog body samples, too: if the $\delta^{13}\text{C}$ and carbon content values are within the usual ranges, the ^{14}C date may usually be considered to be reliable.

Full AAA treatment is the recommended procedure for sample pretreatment. This is generally the case in ^{14}C dating, and has now been found to hold for bog bodies, too. In view of the delicate nature of the samples, the standard pretreatment procedure may be adapted slightly and the reactions may be conducted at room temperature for a shorter duration, using a more strongly diluted acid bath ($<1\%$ HCl).

We should add that materials treated for preservation purposes (for example using substances like paraffin) should not be used for radiocarbon dating as the complete removal of such contaminants cannot be guaranteed.

In conclusion, we have shown that in almost all the cases studied AAA pretreatment results in reliable ^{14}C dates for bog bodies. In most cases, reliable results were also obtained after only step A of the pretreatment procedure. In the case of extremely fragile samples ^{14}C dating without pretreatment may sometimes, but not always, yield correct dates.

Samples of skin, wool, textile or leather are also recommended for ^{14}C dating of bog bodies. Hair may also be used, but that will usually be a very delicate material.

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